Impact of the Early Lutetian C21r-H6 carbon-cycle perturbation on calcareous nannofossils and shallow ocean dynamics (Gorrondatxe, Western Pyrennees)

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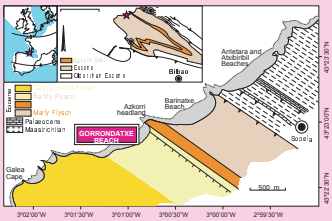
INTRODUCTION

The Eocene Epoch was characterized by overall warm temperatures and superimposed multiple hyperthermal events, such as the well-known PETM, ETM2 and ETM3 events (Zachos et al., 2005; Cramer et al., 2003; Agnini et al., 2009). The present study aims to characterize the environmental effects of the C21r-H6 hyperthermal event. This event, which occurred in Middle Eocene (Lutetian) times, was first defined by Sexton et al. (2011). Later, Payros et al. (2012) identified this hyperthermal in Gorrondatxe and determined that it was characterized by a >1‰ decline in $\delta^{13}C$ and that it lasted 226 kyr (47.44-47.214 Ma). As a supplement to previous stable isotope, mineralogy and foraminifera information (Payros et al., 2012), calcareous nannofossil data are reported herein. Our new study focused on a 400 kyr interval extending from before the hyperthermal event to its aftermath.

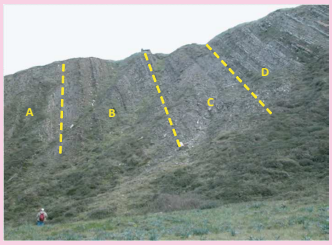
GEOLOGICAL SETTING

The Gorrondatxe section is located in the Basque-Cantabrian basin in the Western Pyrenees. The hemipelagic and turbiditic deposits accumulated at approximately 1500 m water depth. The GSSP for the base of the Lutetian Stage is located in this succession, just 30 meters below the section analyzed in this study.

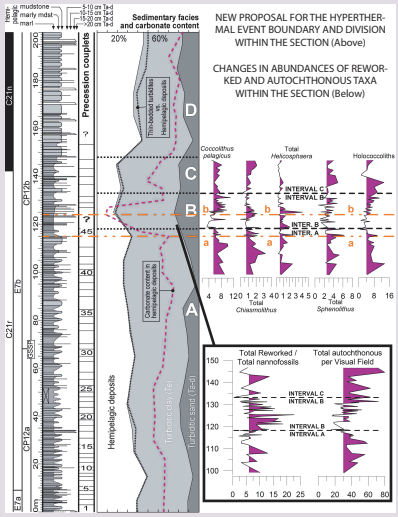


Location of Gorrondatxe Beach in Biscay (Western Pyrenees)

Distal view of Gorrondatxe beach



Proximal view of the section. Note the 4 intervals defined by Payros et al (2012)



Stratigraphic column by Payros et al. (2012). Interval B represents the hyperthermal event. Interval A and D correspond to the previous and aftermath periods. Interval C represents the recuperation from the event.

The total of autochthonous genera decreases significantly during the hyperthermal event, which may have resulted from a dilution of the carbonate fraction due to increased terrestrial clay supply. The increase in the percentage of reworked taxa supports this hypothesis.

In purple lines, we suggest that the event could have started on meter 115 (a), and can be divided into two parts (b).

METHODS

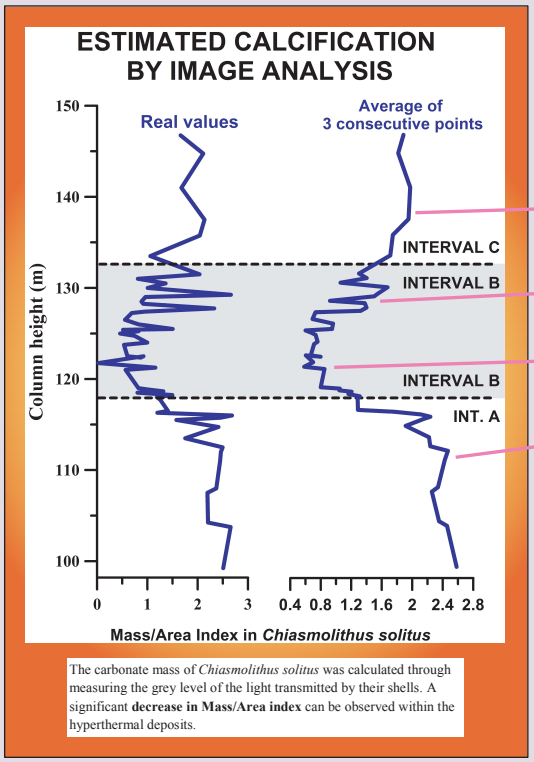
Sixty samples were collected, 15 samples below the hyperthermal event, 36 within the key interval and 9 above. Samples were prepared using the decantation method (Flores and Sierro, 1997). The variations of several nannofossil genera were analyzed by counting 500 fossils per sample. In addition, calcification of the shells was measured by image analysis method (Fuertes et al., 2014), estimating the shell width from the grey level of the polarized light on the microscopy. This study was carried out in the species *Chiasmolithus solitus*, one of the species that most suffers dissolution (Schneider et al., 2011).

RESULTS

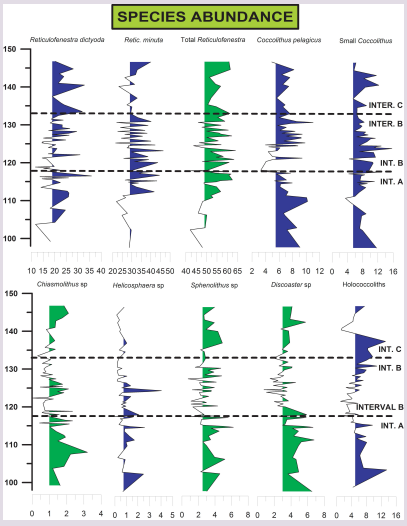
Up to 98 autochthonous species and 15 reworked genera were identified. The total amount of autochthonous species decreases significantly in the hyperthermal deposits, whereas the proportion of reworked genera increases.

Significant changes occurred to the majority of the autochthonous genera. *Reticulofenestra dictyoda*, *Coccolithus pelagicus*, *Chiasmolithus* sp, *Sphenolithus* sp, *Discoaster* sp and holococcoliths decrease significantly in abundance, while a little increase can be observed in *Reticulofenestra minuta, Reticulofenestra* sp, *Helicosphaera* sp and small *Coccolithus* (*Coccolithus pauxillus* group).

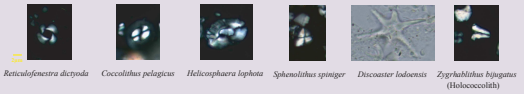
The image analysis showed that the mass/area index of the *Chiasmolithus solitus* shells decreased significantly during the hyperthermal event.



The carbonate mass of *Chiasmolithus solitus* was calculated through measuring the grey level of the light transmitted by their shells. A significant **decrease in Mass/Area index** can be observed within the hyperthermal deposits.



Changes in different taxa's abundance from meter 99 to 147: Cold temperature indicator *Chiasmolithus* decreases; warm temperature and oligotrophy indicators *Discoaster* and *Sphenolithus* decrease; high productivity indicator *Reticulofenestra* increases; low salinity indicator *Helicosphaera* increases.



DISCUSSION

The beginning of the hyperthermal event has previously been discussed by Payros et al. (2012). The nannofossil data suggests that, in effect, the event may have started a few meters below: Concretely in meter 115 of the column. On the other hand, we suggest that the interval itself could be divided into two parts, starting from the line that we have plotted in meter 126, after which a recuperation may have started from the hyperthermal.

The decrease in the total amount of autochthonous species may correspond to a real decrease of the nannofossil abundance during the event, or may be attributable to the increase in the amount of siliciclastic material coming from the continent. Waiting for further data related to the concentration of siliciclastic material in the sediment, at present, **dilution of the autochthonous components due to continental contribution** makes more sense. This is supported by the increase of reworked taxa.

Concerning the **temperature** information given by coccoliths, there is a strong **contradiction** between different **indicators**: The decrease in the abundance of the genus *Chiasmolithus* supports higher temperatures, whereas genera *Discoaster* and *Sphenolithus* support the contrary (Aubry, 1992; Haq et al., 1977; Wei and Wise, 1990). The interpretation of *Coccolithus pelagicus* is not clear, since it is not certain its significance in the Paleogene, although it is linked to cold temperatures in the present. The decrease of *Discoaster* and *Sphenolithus* may be attributable to a different factor, **an increase in nutrient input**. Both genera are catalogued as stratified water inhabitants, which suggests a scenario in which the **high continental contribution led to the mixture of shallow marine waters and its destratification**. The continental contribution is also endorsed by the increase of *Reticulofenestra* sp, which has traditionally been considered as an indicator of **eutrophic conditions** (Bralower, 2002; Villa et al., 2008). Its consequence may have been the **decrease of water salinity**, which could also be associated to the peak of *Helicosphaera* sp (Cachão et al., 2002).

The **calcification** of the nannofossil shells seems to be much **poorer** during the hyperthermal event. This fact could be interpreted as a **decrease in the shallow ocean pH**, rather than a lower original $CaCO_3$ production. Previous research has shown that the lysocline rose during hyperthermal events, providing the acidification of the bottom of the sea, in which nannofossil shells would have deposited, being affected by dissolution (Sluijs et al., 2007; Zachos et al., 2005).

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